United States
Department of
Agriculture

Forest Service

**Rocky Mountain
Forest and Range
Experiment Station**

Fort Collins,
Colorado 80526

**General Technical
Report RM-GTR-291**

Research Needs for Forest and Rangeland Management in Arizona and New Mexico

Abstract:

Evans, Keith E., technical coordinator. 1997. Research needs for forest and rangeland management in Arizona and New Mexico. RM-GTR-291. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 27 p.

As part of a continuous process to identify research needs, this publication provides an update of research needs for Southwestern forests and rangelands. Although the identified research needs are in four categories, integration of research programs is essential to provide the information and technology necessary to enhance ecosystem management practices. The four categories are: 1) human needs and values; 2) wildlife habitat relationships with a threatened, endangered, and sensitive species emphasis; 3) ecosystem health, natural and human disturbances, and restoration; and 4) inventory, monitoring, and assessment.

Workshop participants:

Malchus Baker[1], Bill Block[1], Ward Brady[2], Art Briggs[3], Denver Burns[4], John Conner[3], Madelyn Dillon[4], Lane Eskew[4], Keith Evans[5], Mary Lou Fairweather[3], David Farris[6], Deborah Finch[1], Joe Ganey[1], Gerald Gottfried[1], Sandee Hart[5], Robison Honani[7], Howard Hutchinson[8], Roy Jemison[9], Ann Lynch[1], Alvin Medina[1], John Mitchell[4], Dan Neary[1], Jim Powers[10], Richard Reynolds[4], John Rinne[1], Laurel Wiley[11]

[1]USDA Forest Service Rocky Mountain Forest and Range Experiment Station, Flagstaff, AZ.
[2]Arizona State University, Tempe, AZ.
[3]USDA Forest Service, Region 3, Albuquerque, NM.
[4]USDA Forest Service Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.
[5]USDA Forest Service Intermountain Research Station, Ogden, UT.
[6]University of New Mexico, Albuquerque, NM.
[7]Hopi Tribe Representative Office of Range Management, Kykotsmovi, AZ.
[8]Coalition of AZ/NM Counties, Glenwood, NM.
[9]USDA Forest Service Rocky Mountain Forest and Range Experiment Station, Albuquerque, NM.
[10]Public participant, Prescott, AZ.
[11]USDI Fish and Wildlife Service, Albuquerque, NM.

Cover art by Joyce Patterson.

Publisher:

Rocky Mountain Forest and Range Experiment Station
Fort Collins, Colorado

(To order additional copies of this report or other Station publications, see information on the inside back cover of this report.)

March 1997

Research Needs for Forest and Rangeland Management in Arizona and New Mexico

Keith E. Evans, Technical Coordinator

Contents

Executive Summary

The *Silver vs Thomas* court case of 1996 punctuated conflicts between wildlife and silviculture in Arizona and New Mexico. During the appeal and litigation process, much discussion centered on the amount of scientific information available to land managers. The Forest Service recognized that information gaps to provide a scientific foundation for adaptive management do exist. This publication describes research needs for Arizona and New Mexico that should be addressed by the entire research community to help fill information gaps.

Preparation for this publication began with reviewing research needs documented since 1900. The Forest Service solicited recommendations from experts throughout the agency, other government agencies, tribal councils, special interest groups, and private citizens. Per the *Silver vs Thomas* settlement agreement, a workshop was held in Flagstaff where scientists and other professionals finalized a list of the research needs. Workshop participants identified four categories:

1) human needs and values;

2) wildlife habitat relationships with a threatened, endangered, or sensitive species emphasis;

3) ecosystem health, ecosystem disturbance, and restoration; and

4) inventory, monitoring, and assessment.

Participants concluded that the role of humans and their responsibility to sustain ecosystem function is unclear. Lack of consensus on social values and objectives contribute to current conflicts and complicate land management decisions. Therefore, Southwestern resources and management strategies to sustain ecologic, economic, and cultural well-being need to be better defined.

Participants also concluded that research should better describe habitat requirements for all native species. An ecosystem approach would identify baseline conditions and evaluate the effects of land management on wildlife and habitat. Research should focus on the interactions among composition, structure, function, processes, and landscape pattern within certain vegetation cover types. This approach would help resolve conflicts between management guidelines for individual threatened, endangered, and sensitive (TES) species and all other resources.

Information is needed about the effects of natural and human disturbances on Southwestern ecosystems, including the magnitude of instability and the precise condition of ecosystem health. Historic and prehistoric ecosystem functions, processes, dynamics, and conditions need to be better understood. Then social, economic, and political criteria need to be developed to help determine restoration potential. Further, it is critical to develop practical techniques and methods to restore and maintain ecosystems

Conflicts about adaptive management of forests and rangelands can often be traced to inadequate inventory and monitoring data. Therefore, there is an urgent need to develop methods for inventorying and monitoring species, especially TES species. Methods are important to quantify the current state of an ecosystem and significant ecological trends occurring over time. Land managers can use this information to assess progress toward desired future conditions.

For researchers to address the needs listed herein, decision makers must continue to support research programs and foster a stronger collaboration between researchers and managers to ensure that research results are accomplished and communicated in a useful form. Expertise and technology must be available for continued investigation of research needs in Arizona and New Mexico. A summary of current Forest Service research efforts is included in this publication.

Research Needs for Forest and Rangeland Management in Arizona and New Mexico

Introduction

The Forest Service is legislatively mandated by the Forest and Rangeland Renewable Resources Planning Act of 1974 (P.L. 93-378, 88 Stat. 476, as amended) to ensure that "the new knowledge derived from coordinated public and private research programs will promote a sound technical and ecological base for effective management, use, and protection of the Nation's renewable resources." Based on this mandate, the mission of Forest Service Research is to serve society by developing and communicating the scientific information and technology needed to protect, manage, and use the natural resources of forest and rangelands. Using the scientific method to address critical ecological and human needs, Forest Service scientists and their cooperators develop new information and summarize, develop, or synthesize existing information. This information improves the understanding of fundamental physical, biological, and social processes and forms the basis of environmental policy and natural resource management.

Publications addressing research needs, priorities, and information gaps for adaptive management strategies consistently identify a few specific research topic areas. These include: human needs, values, and expectations; ecosystem dynamics, structure and function; water quality, quantity, and management; vegetation management; integrated systems/decision support models; control of invasive and exotic weeds; protecting threatened, endangered, and sensitive species; ecosystem inventory, monitoring, and assessment; disturbance dynamics; restoration ecology; and wildlife habitat relationships. This publication describes research needs that should be addressed by the scientific community. Other efforts are in progress to describe the state-of-the-knowledge of Southwest ecosystems.

Because there are more research needs than can be addressed by Forest Service scientists and their cooperators, identification is a continuing process that maintains the visibility of the highest priority research needs and information gaps for those who influence research programs. Although the effort reported here was initiated by the court settlement *Silver vs Thomas* (1996), it was designed to meet the following objectives:

1. Identify major information gaps and the corresponding research needed to provide a scientific foundation for adaptive management of Southwestern forests and rangelands by synthesizing information from the most knowledgeable contributors available.

2. Widely disseminate those findings to guide the selection of future research and administrative studies, and to maximize the value of current and future research expenditures. This information is valuable to the entire research community including the private sector, universities, the Forest Service, and other federal and state agencies.

Methods

The research needs listed in this publication are the result of a four-stage process: 1) the emphasis and time frame established by the *Silver vs Thomas* settlement agreement; 2) a review of past Southwest research-needs publications; 3) two draft document mailings to a broad range of interested individuals; and 4) a workshop in Flagstaff, Arizona. Each stage is described below.

1. *Silver vs Thomas* – Item number 7 in the settlement agreement from this court case stated, " . . . the Rocky Mountain Research Station will conduct a workshop to identify research needs for forest management in Arizona and New Mexico, including but not limited to, the research needs for federally listed species. The Station will publish this report within 18 months of the entry of the judgement herein." Extensive discussion occurred during the appeal and litigation process. One point of conflict was a lack of understanding about the extent of information available for management and adaptive management decisions.

2. Research needs review – The Forest Service has identified and evaluated research needs since the early 1900s. Many publications and reports addressing research needs were reviewed to provide a foundation for this report. The findings of these previous efforts are incorporated into this publication. A list of some of the significant publications that were reviewed is in the "Additional Reading" section of this publication.

3. Involvement of interested individuals – One goal in the process to identify information gaps and research needs was to involve as many interested people as practical. This was accomplished by reviewing the mailing list that the Southwest Region of the Forest Service (Region 3) uses to comply with National Environmental Policy Act regulations, and by asking Forest Service employees and others to identify those who might be interested in contributing. From this process a mailing list of approximately 75 individuals and organizations was established. This list included representatives from the Forest Service, various universities, other federal and state agencies, tribal councils, special interest groups, and private citizens.

   An initial draft manuscript was prepared by Keith E. Evans, Assistant Station Director, Intermountain Research Station, Ogden, Utah. The draft was sent to those on the mailing list for their review and feedback. Responses were incorporated into a second draft manuscript and again sent to those on the mailing list. After incorporation of comments from this second review, a third draft manuscript was developed that provided the foundation for a workshop.

4. Research needs identification workshop – As a result of an invitation to 75 potential participants, a group of Forest Service scientists and other professionals attended a workshop in Flagstaff, Arizona on September 16 through 18, 1996. Workshop participants are listed on the inside front cover of this publication. Participants discussed, developed, and finalized a report on information gaps and research needs for forest and range resources in Arizona and New Mexico. The workshop began with a discussion of the process and the prior results. To organize the materials, participants discussed and identified 4 broad research-needs categories: 1) human needs and values; 2) wildlife habitat relationships with a threatened, endangered, and sensitive (TES) species emphasis; 3) ecosystem health, natural and human disturbance, and restoration; and 4) inventory, monitoring, and assessment. Breakout groups then developed and documented the substance of each category. A manuscript was developed based on contributions from the interested individuals and those involved in the workshop. This publication is the culmination of the above process.

There was some discussion regarding the meaning of various words used throughout this document. In an effort to increase the usability of this publication by readers with a broad range of interests and specialties, a glossary of terms is provided in Appendix C.

The Forest Service's ongoing research efforts are recognized in the "Current Forest Service Research Efforts" section of this volume. This publication was not intended as a literature review of current research results; there are other ongoing efforts to synthesize and analyze the volume of available literature.

Human Needs and Values

Although over 99 percent of geologic time existed before humans, primeval, pristine nature exclusive of human involvement no longer exists. All ecosystems are integrated with and affected by humans. People and natural resources are inseparable. Ecosystem management concerns sustaining a healthy and productive environment, which includes people and their relationships with ecosystem components and biological capabilities.

Southwestern ecosystems have evolved under human influence for at least 12,000 years. Throughout this time, there have been several dominant cultures and many levels of human occupancy. Currently, these ecosystems are experiencing increasing human induced changes including population growth, introduction of new plant and animal species, land use changes, and sometimes, accelerated environmental degradation.

USDA Forest Service photo by Tom Traci.

The broad range of environmental opinions held by different individuals and groups often create conflict. Some consider humans to be abusers of the environment requiring stringent control to mitigate their adverse affect on natural resources. Others believe that because humans are the dominant species, they are justified in their exploitation of the land and its resources. Because human survival and the quality of life depends on healthy ecosystems, most people understand that some level of optimal use in conjunction with sustainability of natural resources is necessary. On most public lands, climate, fire, and cosmic and geological disturbances coupled with natural selection and evolution direct major ecosystem changes over time. The exact role of humans and their capabilities to redirect ecosystem function is unclear.

Ecosystem management is an approach to natural resource management that considers management activities within the context of ecologic, economic, and social interactions. This approach is based on the philosophy that knowledge and technology can be used to encourage desired ecosystem conditions for environmental, economic, and social benefits for current and future generations. Inherent in this land ethic are concepts of human needs, administrative coordination, ecological principles, and sound science.

The values of a society partially determine the social objectives that drive land management decisions and research needs. Societal values are expressed in laws, regulations, and Forest Service land management plans. Current Forest Service policy embodies broad societal values in the management of our National Forests. Management policy includes maintaining healthy ecosystems through species protection and restoration of at-risk and unhealthy ecosystems, while continuing to provide multiple- use benefits to society. Maintaining ecosystem health and sustainability are key goals of public land management.

Information about Southwestern resources and resource-management strategies to sustain economic well-being and cultural diversity are inadequate. Current and

future research efforts should address the following information gaps, which are contributing to conflicts.

- Determine the implications of economic shifts and develop ways to cope and thrive as economies shift from industrial based to service and tourist based. Improve our understanding of the effects of outdoor recreation demands on rural communities.
- Improve information on the monetary valuation and economic impact of recreation on public lands. Improve understanding of recreation demands as influenced by fees, facilities, crowding, access, and other variables.
- Improve technology to promote communication among individuals trained in different disciplines and among professional land managers and the public.
- Expand information and techniques to help visitors understand the dynamics of forest and rangeland ecosystems.
- Identify and evaluate the social and economic consequences of public land area designations such as Wilderness, Areas of Critical Concern, Wilderness Study Areas, National Parks, National Monuments, Wild and Scenic Rivers, Wildlife Refuges, Resource Conservation Areas, Research Natural Areas, etc. Answer questions such as: What value do people place on these designations? How will the public benefit from a vigorous program to protect ecosystem integrity on special land designations? How will land managers benefit by using these areas as baseline or reference areas?
- Examine and determine the role of past and present cultural differences in land and resource use, and in perceptions of resource sustainability throughout the Southwest. Use information from other cultures, such as Asian, African, Anasazi, to determine prehistoric, historic, and present land values and uses.
- Continue to integrate agency culture, risk assessment, and decision support systems to facilitate conflict resolution. Develop better techniques to mitigate conflicts through interpretative programs.
- Evaluate or develop methods and technologies to determine the effects of land use and management, such as prescribed fire, on archaeological sites. Improve technology to protect archaeological sites.
- Continue to evaluate and improve management technology to determine the effects of forest and rangeland management activities on visual quality and on the visual expectation of public land users.
- Use archaeological and historical data to develop an improved understanding of the characteristics of sustainable land and resource management with emphasis on institutional complexity, resource use, technology, and public support.
- Improve measures to determine the appropriate balance between ecological and human demands to assure sustainable futures.
- Assess the economic value of soil and water issues including the consequences of erosion, sediment costs, accumulation of trace elements in eroded material, loss in site productivity, affects on vegetation vigor, etc. Continue to evaluate the effects of increased populations and urbanization on surface water quality and quantity.
- Analyze public values and attitudes about water and water management in arid environments, and use this information to improve land management practices.
- Develop a better understanding of "publics of place" and "publics of interest" and their differing views and expectations.
- Identify the prehistoric and historic human contributions to the range of historic and contemporary ecosystem variation. Establish information on prehistoric and historic changes in the Southwest. Improve understanding of the evolution of Southwestern ecosystems.
- Develop protocols to evaluate use of citizen volunteers to help accomplish agency land management goals, and to help the agency better understand user expectations (see parallel research need in the "Inventory, Monitoring, and Assessment" section of this publication).
- Develop conflict resolution methods to help achieve consensus when implementing land management activities.

Wildlife Habitat Relationships

Ecosystem management requires basic and intimate knowledge of ecosystem composition, structure, and function. Plants and animals are intricately linked with their environment. Consequently, organisms need to be studied in the context of their ecological relationships and functional roles within an ecosystem. Because composition, structure, and function vary across vegetation cover types, emphasis should be on ecosystem structure and function, ecological relationships, and multiple-species management, which includes all members of food webs and their habitats. The particular species of most interest will vary depending upon the vegetation cover type (*table 1*). Research that focuses on ecosystem structure and function will provide the knowledge and technology necessary to describe the habitat requirements of all native species in an ecosystems.

An ecosystem focus may help resolve conflicts between management guidelines for individual species at risk, usually TES species. Southwestern TES species are listed in Appendices A and B. The approach described here, acknowledging some overlap, requires basic research to identify baseline conditions and applied research to evaluate the effects of land management practices on ecosystems and populations of native species.

Basic ecosystem research needs, focused by vegetation cover types, should provide information on composition, structure, function, processes, and landscape pattern, and on the interactions among all of these and among vegetation cover types in a landscape. Basic ecosystem research needs include the following.

- Investigate the ecological relationships of plants and animals with special emphasis on TES species. Consider biotic and abiotic components, special habitat components, and spatial-temporal dynamics. Concentrate research on the ecological dynamics of disturbance factors that influence

Rocky Mountain Bighorn Sheep photo by Lane Eskew.

vegetation composition and structure, habitat fragmentation, and landscape patterns.

- Focus basic research on TES species in general; wide-ranging, top-level consumers and other umbrella TES species; endangered, rare, or unique ecosystems; areas, habitats, or ecosystems containing concentrations of TES species; and species having widespread problems in most ecosystem types to help land managers prioritize limited research funds.
- Quantify the natural variation in population size, habitat, food use, distribution, reproduction, and geographic range of selected species. Identify additional causes of any natural variation including variation in cone crops, aquatic insects, weather, or natural disturbances. Understanding the extent and causes of natural variation provides a background for assessing patterns in managed landscapes.

Table 1. Habitats and species requiring special attention.

Habitats	Species
Old-growth forests	Mexican Spotted Owl Northern Goshawk
Riparian ecosystems	Southwestern Willow Flycatcher Least Bell's Vireo Yellow-billed Cuckoo Leopard Frogs
Native grasslands	Mountain Plover Baird's Sparrow Least Tern Piping Plover Lesser Prairie Chicken Sagebrush Lizard
Stream ecosystems	Apache Trout Gila Trout Colorado Spinedace Loach Minnow Roundtail Chub Razorback Sucker Colorado Squawfish Spikedace
Bat habitats	Long-tongued Bat Western Mastiff Bat Big Free-tailed Bat Spotted Bat Allen's Big-eared Bat Townsend's Big-eared Bat Mexican Long-nosed Bat Sanborn's Long-nosed Bat Several "Myotis" Bats

- Increase understanding of neotropical migratory birds including population changes, productivity, predation, competition, habitat fragmentation, and changes in habitat capability through land use patterns and intensity.
- Develop methods to quantify the effects of forest and rangeland management practices on the population levels and dynamics of reptile and amphibian populations.
- Continue or initiate long-term studies designed to determine the life history attributes, habitat associations, relative abundance, reproductive biology, and potential risk factors of rare species.
- Identify and evaluate relationships between water quality criteria and population levels of aquatic macroinvertebrates, fish, and other indicators.

Applied ecosystem research needs, focused by vegetation cover types, should consider effects singly and in combination. Applied research findings should provide a better understanding of current conditions, such as forests dominated by mid-seral stages, then determine the potential ecological pathways and time frames necessary to achieve desired future conditions. Applied ecosystem research needs include the following.

- Investigate the effects of land management practices on indicators of biodiversity and ecosystem health. Consider biotic and abiotic components, special habitat components, landscape pattern, and spatial-temporal dynamics. Suggest adaptive management strategies to achieve desired future conditions.
- Focus research on TES species particularly wide-ranging, top-level consumers, or other umbrella species. Synthesize and interpret information, and assemble it into a format, such as a decision support model, useful to land managers.
- Expand methods to identify direct and indirect effects of land management practices on distribution, habitat use, and focal species populations. Direct effects influence habitat quality by directly changing vegetation structure and composition. Indirect effects operate primarily through their influence on prey species, competitors, predators, or other food sources, for example, acorn production.
- Evaluate the effects of management practices on habitats used for nesting, roosting, foraging, dispersal, or other activities by the focal species and/or other members of their food web. Develop improved decision support systems to adapt

management practices to benefit wildlife species at risk.

- Identify information gaps in existing habitat conservation plans. Determine whether the habitat conditions recommended in these plans provide for the needs of all species in a vegetation cover type.
- Determine the roles of rare and unique habitats in ecosystem processes and health, and the contributions these habitats make to biodiversity.
- Determine new ways that current research on ecosystem and site conservation thresholds can be used in decision support models.
- Determine the effects of exotic and invasive species on wildlife populations with emphasis on native species at risk.
- Continue to evaluate the effects that manipulating riparian and instream habitat characteristics, through grazing, water diversions, recreation use, etc., has on endemic fish populations. Assess minimum water flow rates and required flow variations to maintain viable populations of native fish populations. Synthesize and interpret information, and assemble it into a format useful to land managers.
- Synthesize available data on wildlife and forest requirements to recommend ecosystem management practices that will preserve desirable forest and wildlife habitat conditions.
- Determine ways to remove obstacles that prevent trout and small nongame fish species from migrating among streams, which is necessary for metapopulation dynamics. Determine what conditions are required to ensure that structures placed in water channels are improving fish habitat and watershed conditions.
- Develop integrated management techniques for minimizing cowbird brood parasitism on neotropical migratory bird species at risk.

Ecosystem Health, Natural and Human Disturbance, and Restoration

An increasing human population and rapid advances in technological development and chemical production have accelerated worldwide ecosystem stresses. Many Southwestern ecosystems have been compromised by mining, hazardous substances, logging, grazing, recreation, and fire exclusion. These stresses result in ecosystems unable to meet current and future needs due to an inability for renewal, a lack of resilience, and an inherent instability. The magnitude of instability and the precise condition of ecosystem health are unknown.

Effective implementation of ecosystem management requires a better understanding of ecosystem dynamics than is currently known. This information gap is particularly critical to TES species and their habitats. A better understanding of landscape disturbance ecology is necessary for improved maintenance, conservation, and enhancement of wildlife species and habitats. A basic comprehension of ecosystem structure, function, and dynamics is key to improved resource management. Disturbance agents can be natural, such as fire, insects, diseases, climate, erosion, herbivory by native fauna, and invasion by flora and fauna, or human such as the introduction of exotic species, fire exclusion, tree harvesting, prescribed fire, domestic livestock grazing, range management practices, water development, urban expansion, recreation, mining, and oil and gas development. Land use practices in the Southwest have produced forests dominated by mid-seral successional stages. Desired future conditions should be defined in terms of current conditions and future potentials.

The Forest Service has historically been concerned about forest and rangeland health; specifically, susceptibility to pests, disease, and wildfires. Forest and rangeland health is when ecosystems have the capacity for renewal,

USDA Forest Service photo by Lee Carr.

for recovery from a wide range of disturbances, and for retention of ecological resilience. Ecosystem health must be considered in conjunction with the current and future needs of people for values, uses, products, and services.

Ecosystem health, natural and human disturbance and restoration research needs are grouped into the following 5 general areas. Each general area has specific research needs listed.

1. **Develop a better understanding of historic and prehistoric ecosystem functions, processes, dynamics, and conditions, allowing for a temporal factor in pre-existing conditions.**

   - Determine the impact level of pollutants on cave development and cave species richness, and determine if there is a relationship between air quality and the pollutant level. Assess the opportunities for restoration of degraded cave systems.
   - Better define and understand the natural range of fire variability in ecosystems regarding frequency, extent, severity, and season.
   - Describe and evaluate the processes that control and moderate the natural variability of fire regimes.
   - Increase understanding of how fire, insects, diseases, and climate interact and maintain the health of Southwestern ecosystems including aquatic and riparian habitats.
   - Determine how prehistoric and historic land uses, such as harvesting, agriculture, grazing, and water and mineral development, influenced Southwestern ecosystems.
   - Where inadequate, increase information about the historic distributions and density of forests, woodland, and grassland ecosystems to better describe desired conditions at landscape scales.
   - Improve knowledge of the growth, yield, mortality, and regeneration of forest and pinyon-juniper woodlands in Research Natural Areas and other reference areas to improve decision support models.
   - Quantify the associations between management activities and riparian ecological functions that sustain biodiversity. Develop decision support models to assist managers in selecting the best management practice for specific situations.
   - Quantify and predict the impact of grazing, fire, and vegetation management on sediment movement and water quality, and determine the effectiveness of different conservation measures in maintaining water quality.
   - Continue to evaluate the long-term impacts of domestic livestock grazing on Southwest ecosystems that did not evolve with herbivory by large animals such as elk or bison; emphasize understanding the impacts on soils, plants, wildlife, and hydrology.
   - Determine trends in soil loss and gain during recent human occupancy and relate these trends to plant community sustainability, plant vigor, plant composition, and arthropod populations. Use this knowledge to assess the potential for restoration practices.

2. **Develop social, economic, and political criteria for determining whether an area needs to be, can be, and should be restored.**

   - Determine the threshold levels at which it is impractical to attempt restoration. Develop risk analyses techniques to determine the consequences, for example, significant biodiversity loss, of not attempting restoration.
   - Improve evaluation technology to determine when ecosystem health reaches the threshold at which abiotic and biotic resources are being lost or the thresholds at which instability is negatively impacting other ecosystems.
   - Evaluate the economic factors associated with restoring ecosystems including the investment needed to attain the desired condition.
   - Develop additional indicators or metrics to evaluate the social and cultural consequences of restoration, to assess forest and rangeland health, and to determine when restoration becomes a disturbance that outweighs the intended benefits.

3. **Better define the cumulative and interactive effects of disturbances and management activities on biodiversity, including TES species, with particular emphasis on key disturbance factors such as noxious and exotic weeds, insects and diseases, grazing, logging, and fire.**

   - Assess the effects of invasive and exotic species on habitat for TES species. Continue to improve guidelines for adaptive management planning concerning invasive and exotic species.
   - Evaluate current silvicultural prescriptions for effectiveness at enhancing wildlife habitats, allowing tree commodity production, and reducing risk of undesirable disturbances by insects, diseases, weeds, and wildfire. Develop new silvicultural techniques if needed.

- Determine the inter-relationships of fish habitat and populations to streamflow regimes, stream morphology, coarse woody debris, riparian vegetation, and bank erosion. Validate watersheds models in the Southwest to enhance integrated management practices.
- Quantify the dynamics of water flux between surface and ground water sources, and its affect on associated riparian vegetation and instream flow regimes.
- Improve knowledge on the effects of fire frequency, intensity, and timing on grassland and shrubland ecosystem condition, function, and processes. Provide associations to management goals such as maintenance of biodiversity and productivity.
- Continue to evaluate the effects of different grazing systems, rotations, and stocking rates on TES fauna and flora in desert and plains grasslands.

4. **Evaluate the effects of disturbances on ecosystem function, processes, and components.**
   - Where knowledge gaps occur, determine the regeneration dynamics of herbaceous and woody species following disturbances with emphasis on species important to restoration projects.
   - Continue research to determine the effects of disturbances, such as salt cedar invasion, grazing, water manipulations, recreation, and fire, on neotropical migrating bird populations in riparian habitats. Additional information is needed to improve land management decisions.
   - Determine the interactions between riparian, vegetation, geomorphology, sediment transport process, and channel dynamics in mid- and low-elevation streams and montane cienegas as related to disturbances.
   - Evaluate the effects of hydrologic disturbances and invasive and noxious weeds on playa and grassland ecosystems.
   - Determine the role of grassland arthropods as disturbance agents, and determine their relationship to other disturbance agents.
   - Determine the role of insects and diseases in creating gaps in forests and woodlands, and determine how they function in influencing wildlife and their habitats.
   - Evaluate the ecological role and consequences of salt cedar and other opportunistic species on the viability of endemic species.
   - Continue research to determine the effect of fire, grazing, and logging on tree and understory plant density, and the consequent responses of wildlife species and watershed values.
   - Identify fire-dependent wildlife species and evaluate the ability of current disturbance agents to provide suitable habitats.
   - Increase research on ecosystem function to determine the wildlife species that require old growth forests and/or large whole forest blocks and those that require early, mid- and late successional habitat blocks. Determine the roles and functions of ecotones (edge habitats) in ecosystem processes, especially on wildlife habitat requirements.
   - Better assess the effects of frequent prescribed fires on soil nutrients in woodlands and semi-desert grasslands.

5. **Develop, compare, and modify techniques and methods to restore and maintain ecosystems.**
   - Increase the knowledge about how different management regimes, such as uneven-aged and even-aged silviculture, affect the dynamics of insect and disease populations.
   - Develop risk rating systems to determine when and how insect and disease populations cease to function within natural or desirable ranges of variability.
   - Compare the effectiveness of techniques for restoring grassland communities that have become dominated by mesquite, creosote, and/or juniper. Identify causes of degradation and how ecosystem processes are affected. Continue to develop and compare methods like biological control, grazing management, fire, and herbicide treatment for ecosystem restoration.
   - Develop improved restoration techniques for recovering declining wildlife populations and their habitats. Improve technology for protecting, conserving, and restoring rare, unique, and endangered habitats and build these new techniques into decision support models.
   - Evaluate the tradeoffs between prescribed burning and air quality when fire is used as an ecosystem restoration tool.

- Integrate and validate physical and vegetation classification systems for stream-riparian ecosystems to guide riparian restoration projects.
- Compare vegetation successional dynamicsunder different restoration regimes and evaluate animal responses under different restoration-imposed vegetation successional pathways.
- Identify effective methods and appropriate areas for recovering declining neotropical bird and bat populations.
- Determine additional techniques to redistribute nutrients in degraded ecosystems to improve the effectiveness of restoration programs.
- Determine the desirable levels of shrub and tree regeneration to sustain healthy stands in forests and woodlands.
- Determine if new silviculture methods can be used to sustain or hasten the development of old-growth forest and woodland characteristics.
- Understand the response of aquatic TES species and sport fish populations and their habitats to ungulate grazing and prescribed fires. Provide a foundation to improve management plans for Southwestern aquatic ecosystems.
- Expand guidelines for assessing levels of stream disturbance and recovery rates of riparian vegetation and soils in montane riparian areas to establish TES fish stocking capacity.
- Determine the effects of large floods on aquatic fauna and flora in riparian zones relative to other disturbances, and determine indicators of expected rates of recovery.
- Expand guidelines for restoring hydrologic regimes and functions of montane cienegas to sustain native fish populations following erosional disturbances, ungulate grazing, fire exclusion, etc.

Inventory, Monitoring, and Assessment

Monitoring, essential for management and research, is often poorly defined and misunderstood. In this publication, monitoring means a process of systematically tracking the way ecosystems, including the human dimension, respond to management and natural changes. Monitoring is critical to determine direction and rate of progress toward or from a desired future condition, and it provides valuable scientific information about the way ecosystems function. Conflicts and disagreements about proper management goals and alternatives can often be traced to inadequate inventory and monitoring data that characterize ecosystem function and dynamics. This lack of information is particularly evident in areas of forest and rangeland health and biodiversity trends and risks.

The monitoring process is the key feedback loop to assess management actions and provides the basis for adaptive management actions and guidelines for future monitoring (*figure 1*). Adaptive management is: 1) accepted within scientific and management communities as a design for dealing with incomplete information; and 2) an iterative process whereby the results of management are compared to goals provided by society or set by a management agency (*figure 2*). An adaptive process could be effective in overcoming a number of monitoring issues; for example, qualitative management objectives, inconsistent sampling methods, and a lack of parameter information relating to environmental features over time and space. The steps in an adaptive monitoring design include determining the: data use, measures needed, level of sensitivity needed to detect a change level of accuracy required, and types of monitoring techniques to use.

USDA Forest Service photo by Anna Schoettle.

Scientists and specialists of many disciplines are required to address research needs pertaining to ecosystem management of Southwestern forests and rangelands. These disciplines include foresters, range scientists, wildlife biologists, ecologists, entomologists, microbiologists, physical scientists, and social scientists. Each discipline works on important research problems that require inventory and/or monitoring protocols. A goal of natural resource research is to find ways to integrate the needs of all disciplines and define concepts like ecosystem health, biodiversity, sustainability, and a properly functioning condition. Narrow-based, short-term inventory and monitoring projects often lead to conflict and confusion and are ineffective and costly.

There is an urgent need to develop methods to inventory and monitor TES species. Presently, there are inadequate guidelines for locating species, determining abundance and population trends, describing TES species-biotic complex relationships, locating potential habitats, understanding population viability factors, understanding extinction risks, and understanding metapopulation dynamics within multiple habitat patches.

There is an important difference between inventory and monitoring. An inventory

quantifies the state of the ecosystem at a point in time, while monitoring determines if significant ecologically important trends have occurred over time. Some inventories can contribute to monitoring trends if repeated at planned and appropriate intervals. To be useful, monitoring designs should be stable, robust, cost-effective, and powerful enough to detect significant changes. The goal of research in this area is to develop scientifically credible and defensible monitoring protocols that identify ecologically meaningful change within acceptable limits of error. This section identifies inventory, monitoring, and assessment research needs for Southwestern forests and rangelands.

- Understand variations in how members of different cultural groups would conceptualize sustainable development and develop criteria and indicators of sustainability. Develop criteria and indicators to monitor sustainability.
- Determine appropriate indicators, especially at the landscape scale, for determining components of rangeland health based on the National Research Council's proposal that all rangelands be categorized as healthy, at-risk, or unhealthy. In particular, develop ways to validate and discern limits of conceptual models describing healthy ecosystems.
- Validate and expand methods to inventory and monitor TES species on National Forest System land by developing guidelines for locating species and determining population size and trend.
- Develop new and more cost-effective processes for setting and incorporating monitoring goals into sampling designs.

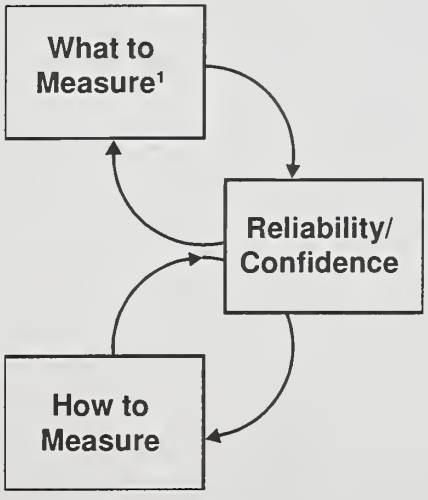

Figure 1. The monitoring process is the key feedback loop to assess management actions.
[1]Kind of data needed and type of measure used.

- Develop assessment tools to describe thresholds or limits to properly functioning conditions in riparian, aquatic, and upland ecosystems.
- Develop protocols and monitoring approaches to strengthen management plans by supporting the processes of adaptive management.
- Develop acceptable sampling methods to monitor changes to ecosystem resilience and TES species that can be conducted by volunteers. Many sampling protocols are expensive and time consuming and although monitoring demands are increasing, budgets are limited. Existing volunteer programs such as "Mothers for Clean Water" in Phoenix, student monitoring of riparian conditions through the College of Santa Fe, the Department of Interior's Breeding Bird Survey, and other established partnerships can be expanded.
- Develop monitoring theories and predictive applications that reduce the need for expensive ground-based data and rely more on remote

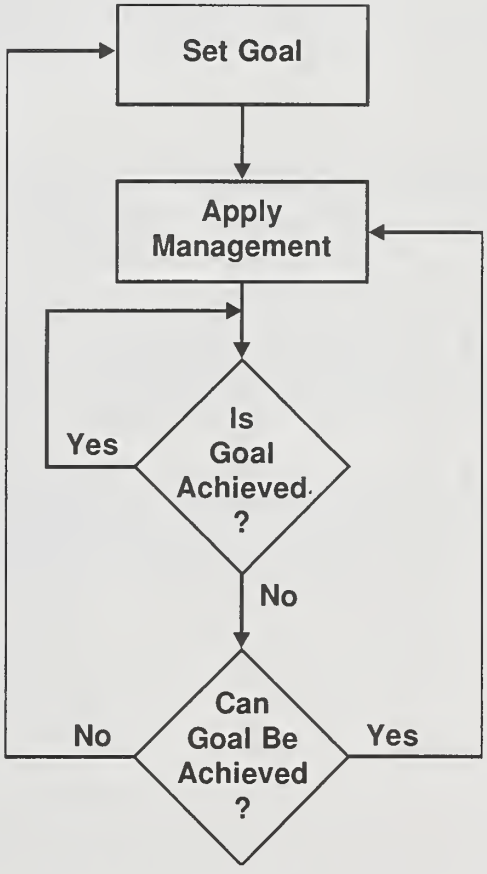

Figure 2. Adaptive management is an iterative process comparing the results of management to specific goals.

sensing and model predictions that have cost-efficient validating protocols.

- Develop innovative quality control protocols to assure and document the accuracy and precision of multidimensional, georeferenced data sets. As data are made available to the public, via on-line electronic services, quality control and knowledge of how information is being used becomes increasingly important.
- Synthesize protocols for monitoring more specific ecological attributes relating to sustainability such as resilience and resistance. If needed, describe new measurable indications.
- Develop new and validate existing cost-effective inventory methods to describe the status of functional processes in upland, riparian, and aquatic ecosystems.
- Develop monitoring protocols to help understand and incorporate changes in public and agency behaviors, and develop expectations to help implement adaptive management philosophies.
- Improve criteria for best management practices and monitoring technology to determine relationships and trends between uplands and corresponding wetlands.

Current Forest Service Research Efforts

Ecological Basis for Research of the Borderlands of the Southwest United States

Research Work Unit 4651
Carleton B. Edminster, Team Leader
240 W. Prospect Rd.
Fort Collins, CO 80526
(970) 498-1264

and

Coronado National Forest
300 West Congress
Tucson, AZ 85701
(520) 670-4568

Mission

To achieve ecosystem management in the borderlands of the Southwestern United States through coordinated research and management partnerships.

Goals

- Establish the desired future condition for the borderlands region based on highest quality ecological science, which is integrated with the social and economic desired conditions within the context of private-agency partnerships.
- Develop and implement a long term, systematic program of basic and applied research and monitoring that integrates past and future research findings.
- Develop guidelines for sustaining a viable rural economy.

Sustainability of Riparian Ecological Systems in Southwestern Forests and Woodlands

Research Work Unit 4302
Daniel G. Neary, Project Leader
Southwest Forest Sciences Complex
2500 S. Pine Knoll
Flagstaff, AZ 86001
(520) 556-2176

Mission

Create, develop, and apply knowledge on fluvial, geomorphological, and ecological system functions, processes, and dynamics needed to sustain diverse, healthy, and productive threatened, endangered, and sensitive fish, plant, and other biotic species within riparian ecological systems of forest landscapes in the arid states of the Southwestern United States and northern Mexico.

Goals

- Determine the specific interrelationships among hydrologic, geomorphic, and biotic processes that affect fish habitat, riparian vegetation, channel dynamics, and instream flow regimes.
- Develop predictive models to determine the effect of watershed-scale activities such as prescribed fire, grazing, and vegetation management on the functioning and quality of riparian ecological systems.
- Determine the factors that influence populations and habitats of threatened, endangered, and sensitive fish, other fish, plants, and other biota in Southwestern riparian ecological systems.

Cultural Heritage Research

Research Work Unit 4853
Joseph A. Tainter, Project Leader
Forestry Sciences Laboratory
2205 Columbia SE
Albuquerque, NM 87106
(505) 766-2384

Mission

To improve understanding of the characteristics of sustainable societies, the cultural dimensions of ecosystem management, and the management and enhancement of heritage resources.

Goals

- Improve understanding of the characteristics of sustainable societies and institutions, with emphasis on complexity, effectiveness, and public support of land management and environmental research.
- Develop understanding of the responses of past societies to episodes of rapid environmental change.
- Improve understanding of cultural identity and cultural conflict and their relationship to disputes over land and other resources.
- Improve understanding of the perceptions and values of land and land management held by North American cultural groups.
- Expand the basis of heritage management through analysis of cultural landscapes, land-use systems, and the past human role in ecosystem processes.
- Conduct research to improve understanding of the factors that influence heritage site distributions and of archaeological indicators of past land users.

Impact of Natural Ecological Disturbances on Western Conifers

Research Work Unit 4152
Karen M. Clancy, Project Leader
Southwest Forest Sciences Complex
2500 S. Pine Knoll
Flagstaff, AZ 86001
(520) 556-2105

Mission

To determine the response of trees to temperature and insect stresses.

Goals

- Understand the seasonal dynamics of cold and heat tolerance of woody plant species and how changing environmental variables will impact forest ecological systems that are both regulated and stressed by high and low temperatures.
- Increase understanding of the physiological mechanisms that determine resistance of trees to damage from the western spruce budworm and of how tree genetics and the environment affect these mechanisms.

Sustainability of Southwestern Forest and Woodland Terrestrial Ecological Systems

Research Work Unit 4251
William M. Block, Project Leader
Southwest Forest Sciences Complex
2500 S. Pine Knoll
Flagstaff, AZ 86001
(520) 556-2161

Mission

Acquire, develop, and apply new knowledge and technology to guide ecosystem management to sustain selected, critical components, such as soils, flora, fauna, and habitats, of population, community, and landscape ecological systems in Southwestern forests and woodlands.

Goals

- Develop an understanding of nutrient cycling and fluxes, biogeochemical cycling, primary productivity, and ecological roles of mycorrhizae that determine the structure and function of ecological systems and how disturbances may affect those processes.
- Develop and apply the knowledge needed to predict how combinations of fuelwood and timber harvest, and grazing and fire affect wildlife habitats.
- Continue to investigate the factors that influence populations and habitats of threatened, endangered, and sensitive species—bald eagle, northern goshawk, and Mexican spotted owl—in Southwestern forest ecosystems.
- Determine factors that influence and limit populations and habitats of passerine birds, reptiles and amphibians, including threatened, endangered, and sensitive species, in Southwestern riparian ecological systems
- Assess the effects and dynamics of land management on populations, distributions, and habitats of neotropical migratory birds.

Ecology, Diversity, and Sustainability of Soil, Plant, Animal, and Human Resources of the Rio Grande Basin

Research Work Unit 4652
Deborah M. Finch, Team Leader
Forestry Sciences Laboratory
2205 Columbia SE
Albuquerque, NM 87106
(505) 766-2384

Mission

To maintain the diversity of native grasslands, shrublands, woodlands, and forests in the Rio Grande Basin. To understand how human use of the Basin's upland environments affects overall ecosystem functioning and structure.

Goals

- Determine short- and long-term responses of upland soils, water, nutrients, mycorrhizae, and vegetation to historic and current perturbations caused by factors such as climate, grazing, fire, fuelwood harvesting, recreation, or farming; clarify how such responses influence dynamics, stability, and productivity of upland ecosystems in relation to site capability.
- Determine past and present spatial and temporal processes within fluvial ecosystems that form major linkages between upland catchments (watersheds), the Rio Grande, and its floodplain bosques.
- Determine how plant and animal species respond to barriers in dispersal, migration, and reproduction along the Rio Grande and selected tributaries; identify those species most sensitive to corridor edges and barriers, and develop methods for enhancing movement and survival of threatened, endangered and sensitive species.
- Improve understanding of the environmental history of the Rio Grande Basin, the historic and contemporary human role in Basin ecosystems, the natural and extent of human disturbances to the Basin, and the sustainability of cultural diversity in the Basin.

Ecology, Recovery, and Sustainability of Grassland and Riparian Ecosystems in the Southwest

Research Work Unit 4351
Deborah M. Finch, Project Leader
Forestry Sciences Laboratory
2205 Columbia SE
Albuquerque, NM 87106
(505) 766-2384

Mission

Develop, synthesize, and apply new knowledge on processes, interactions, and human uses of desert and steppe ecosystems for sustaining intact, productive, and diverse plant and animal communities and associated abiotic systems in the Southwest.

Goals

- Develop site-specific studies that will quantify processes that contribute to rill formation, arroyo development, and decline in water quality such as diminished infiltration, increased surface runoff and soil erosion.
- Assess edaphic interactions with macroflora and microorganisms, including nutrient dynamics, carbon budgets, and maintenance of root shearing strength, to elucidate their relationship to degradative processes.
- Determine roost requirements, habitat use, and foraging behavior of selected bat species to predict effects of land management activities on bat habitat quality, reproductive success, and population status.
- Establish landscape-scale studies to address the multiple and cumulative effects of smaller scale, site-level dynamics occurring over larger land areas and across public and private ownerships.
- Quantify the roles and influences of grazing and fire on ecosystem stability, succession, and retrogression, as well as the relationships and threats to water, soil, plants, and animals found in stable but degraded states of desert and steppe ecosystems.
- Evaluate how changes in soil productivity and hydrological systems stimulate changes in plant composition, abundance, and structure, which may affect plant/animal interactions and habitat condition, value, and availability.
- Assess the historic and current effects of land use on functioning and dynamics of Southwestern desert and steppe ecosystems through evaluation of ecosystem responses to manipulative treatments over short- and long-term periods.
- Develop and test alternative approaches and techniques for restoring degraded ecosystems; monitor and model recovery responses; and develop monitoring and management guidelines that can be used by land-management agencies.

Additional Reading

Broderick, Stephen H. 1991. **Practicing foresters identify research needs.** Journal of Forestry. 89(8):27-33.

Christensen, Norman L.; et al. 1996. **The report of the Ecological Society of America, Committee on the Scientific Basis for Ecosystem Management.** Ecol. Applications 6:665-691.

Cordell, H. K. 1992. **An evaluation of wilderness research: state of knowledge and research needs for the 1990s.** In American forestry - an evolving tradition: Proceedings of the Society of American Foresters National Convention; October 25-27, 1992; Richmond, VA: SAF publication:196-201.

DeBano, Leonard F; et al., tech. coords. 1995. **Biodiversity and management of the madrean archipelago: the sky islands of southwest United States and northwestern Mexico**: Symposium proceedings; September 19-23, 1994; Tucson, AZ: Gen. Tech. Rep. RM-GTR-264. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station. 669 pp.

Ellison, Lincoln, A. R. Croft; Reed W. Bailey. 1951. **Indicators of condition and trend on high range watersheds of the Intermountain region.** Agric. Handb. 19. Washington, DC: U.S. Department of Agriculture: 66 pp.

Evans, Keith E. 1990. **Rangeland Research: Past, present, and future.** U.S. Department of Agriculture, Forest Service, Forest Environment Research, Washington, DC: 26 pp.

Finch, D. M. 1992. **Threatened, endangered, and vulnerable species of terrestrial vertebrates in the Rocky Mountain Region.** Gen. Tech. Rep. RM-215. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station. 38 pp.

Finch, Deborah M.; Tainter, Joseph A., tech eds. 1995. **Ecology, diversity, and sustainability of the Middle Rio Grande Basin.** Gen. Tech. Rep. RM-GTR-268. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station. 186 pp.

Kaufmann, M. R.; Graham, R. T.; Boyce, D. A.; Jr. Moir, W. H.; Perry, L.; Reynolds, R. T.; Bassett, R. L.; Mehlhop, P.; Edminster, C. B.; Block, W. M.; Corn, P. S. 1994. **An ecological basis for ecosystem management.** Gen. Tech. Rep. RM-GTR-246. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station. 22 pp.

Lee, Kai N. 1993. **Compass and gyroscope: integrating science and politics for the environment.** Island Press: Washington, DC: 243 pp.

Morrisette, Peter M. 1992. **Congress on renewable natural resources: Critical issues and concepts for the twenty-first century.** Renewable Natural Resources Foundation, Renewable Resources Journal. 10 (3):1-31.

Murphy, Dennis, comp. 1992. **Getting to the future through silviculture - workshop proceedings, May 6-9, 1991**; Cedar City, UT: Gen. Tech. Rep. INT-GTR-291. Ogden, UT: U.S. Department of Agriculture, Intermountain Research Station. 97 pp.

National Research Council. 1990. **Forestry Research: A mandate for change.** National Academy Press: Washington, DC: 84 pp.

National Research Council. 1994. **Rangeland Health: New methods to classify, inventory and monitor rangelands.** National Academy Press: Washington, DC: 180 pp.

Roberts, Paul H. 1963. **Hoof prints on forest ranges - the early years of National Forest range administration.** Naylor Co.: San Antonio, TX. 151 pp.

Silver vs. Thomas, October 18, 1996 (CIV-94-00337 PHOENIX PHX-CAM; CIV-94-1610-PHX-CAM Consolidated).

Society of American Foresters. 1980. **Forest Cover Types of the United States and Canada.** F.H. Eyer, Ed. Society of American Foresters, 5400 Grosvenor Lane, Washington, DC: 148 pp.

Society For Range Management. n.d. **Research needs: Grazing lands - the neglected resource.** The Society for Range Management, 1839 York Street, Denver, CO. n.p.

USDA Agricultural Research Service. 1996. **A vision for rangeland research.** Program Aid 1547. Washington, DC: U.S. Department of Agriculture Res. Ser. n.p.

USDA Forest Service. 1944. **The history of western research.** Washington, DC: U.S. Department of Agriculture, Forest Service, Div. of Range Research, Agr. Hist. 18:127-143.

USDA Forest Service. 1964. **A national forestry research program.** Misc. Pub. 965. Washington, DC: U.S. Department of Agriculture, Forest Service: 34 pp.

USDA Forest Service. 1970. **Range ecosystem research: The challenge of change.** Agriculture Information Bull. No. 346. Washington, DC: U.S. Department of Agriculture Forest Service: 26 pp.

USDA Forest Service. 1989. **Forests for American's future: A research program for the 1990s.** U.S. Department of Agriculture, Forest Service, National Association of Professional Forestry Schools and Colleges; U.S. Department of Agriculture, Cooperative State Res. Service, Washington, DC: 32 pp.

USDA Forest Service. 1993. **Healthy forests for America's future: A strategic plan.** MP-1513. Washington, DC: U.S. Department of Agriculture, Forest Service: 58 pp.

USDA Forest Service. 1995. **Agroforestry and sustainable systems:** Symposium proceedings; August 7-10, 1994; Fort Collins, CO: Gen. Tech. Rep. RM-GTR-261. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station. 276 pp.

Appendix A

Threatened and Endangered Species – Forest Service, Region 3[1]

Common name	Scientific name	Status
Mammals		
Bat, Mexican Long-nosed	*Leptonycteris nivalis*	E
Bat, Lesser Long-nosed	*Leptonycteris curasoe yerbabuenae (=sanborni)*	E
Ferret, Black-footed	*Mustela nigripes*	E
Ocelot	*Felis pardalis*	E
Jaguar	*Felis onca*	T
Jaguarundi	*Felis yagouaroundi tolteca*	E
Squirrel, Mt. Graham Red	*Tamiasciurus hudsonicus grahamensis*	E
Vole, Hualapai Mexican	*Microtus mexicanus hualapaiensis*	E
Wolf, Mexican Gray	*Canis lupus baileyi*	E
Birds		
Bobwhite, Masked	*Colinus virginianus ridgewayi*	E
Crane, Whooping	*Grus americana*	E
Eagle, Bald	*Haliaeetus leucocephalus*	E
Falcon, American Peregrine	*Falco peregrinus anatum*	E
Falcon, Arctic Peregrine	*Falco peregrinus tundrius*	T
Falcon, Northern Aplomado	*Falco femoralis septentrionalis*	E
Flycatcher, SW Willow	*Empidonax trailii extimus*	E
Owl, Mexican Spotted	*Strix occidentalis lucida*	T
Pelican, Brown	*Pelecanus occidentalis*	E
Plover, Piping	*Charadrius melodus*	T
Pygmy Owl, Cactus	*Glaucidium brasilianum ferruginous*	T
Rail, Yuma Clapper	*Rallus longirostris yumanensis*	E
Tern, Interior Least	*Sterna antillarum athalossos*	E
Fish		
Catfish, Yaqui	*Ictalurus pricei*	E
Chub, Bonytail	*Gila elegans*	E
Chub, Chihuahua	*Gila nigrescens*	T
Chub, Humpback	*Gila cypha*	E
Chub, Sonora	*Gila ditaenia*	T
Chub, Yaqui	*Gila purpurea*	E
Minnow, Loach	*Tiaroga cobitus*	T
Minnow, Rio Grande Silvery	*Hybognathus amarus*	E
Pupfish, Desert	*Cyprinodon macularius macularius*	E
Shiner, Beautiful	*Cyprinella formosa*	E
Shiner, Yaqui	*Cyprinella formosa mearnsi*	E
Spikedace	*Meda fulgida*	T
Spinedace, Little Colorado	*Lepidomeda vittata*	T
Squawfish, Colorado	*Ptychocheilus lucius*	E
Sucker, Razorback	*Xyrauchen texanus*	E
Topminnow, Gila	*Poeciliopsis occidentalis occidentalis*	E
Topminnow, Yaqui	*Poeciliopsis occidentalis sonorensis*	E
Trout, Apache	*Salmo apache*	T
Trout, Gila	*Onchorynchus gilae*	E
Woundfin	*Plagopterus argentissimus*	E

Common name	Scientific name	Status
Amphibians and Reptiles		
Rattlesnake, NM Ridgenosed	*Crotalus willardi obscurus*	T
Salamander, Sonora Tiger	*Ambystoma tigrinum stebbinsl*	T
Invertebrates		
Ambersnail, Kanab	*Oxyloma haydeni kanabensis*	E
Plants		
Arizona Agave	*Agave arizonica*	E
Kearney's Bluestar	*Amsonia kearneyana*	E
Sacramento Prickly Poppy	*Argemone pleiacantha* ssp. *pinnatisecta*	E
Lee's Pincushion Cactus	*Coryphantha sneedii* var. *leei*	T
Sneed's Pincushion Cactus	*Coryphantha sneedii* var. *sneedii*	E
Kuenzler's Hedgehog Cactus	*Echinocereus fendleri* var. *kuenzleri*	E
Lloyd's Hedgehog Cactus	*Echinocereus lloydii*	E
Arizona Hedgehog Cactus	*Echinocereus triglochidiatus* var. *arizonicus*	E
Holy Ghost Ipomopsis	*Ipomopsis sancti-spiritis*	E
Arizona Cliffrose	*Purshia subintegra*	E
San Francisco Peaks	*Senecio franciscanus groundsel*	T
Pima Pineapple cactus	*Coryphantha scheeri* var. *rubustispina*	T
Madrean Ladies' Tresses	*Spiranthes delitescens*	P
Parish Alkali Grass	*Puccinella parishii*	P
Sentry Milk-vetch	*Astragalus cremnophylax* var. *cremnophylax*	E
Todsen's Pennyroyal	*Hedeoma todsenii*	E
Sacramento Mtn Thistle	*Cirsium vinaceum*	T
Rhizomatus Fleabane	*Erigeron rhizomatus*	T
Umbel, Huachuca Water	*Lilaeopsis schaffnianeria* ssp. *recurva*	P

[1] *Source = U.S. Fish and Wildlife Service*
E = endangered
T = threatened
P = proposed for federal listing

Appendix B

Sensitive Species – Forest Service, Region 3[1]

Animals

Common name	Scientific name
Frog, Barking	*Hylactophryne augusti*
Frog, Chiricahua Leopard	*Rana chiricahuensis*
Frog, Lowland Leopard	*Rana yavapaiensis*
Frog, Northern Casque Headed	*Pternohyla fodiens*
Frog, Northern Leopard	*Rana pipiens*
Frog, Plains Leopard	*Rana blairi*
Frog, Tarahumara	*Rana tarahumarae*
Salamander, Huachuca Sonoran Tiger	*Ambystoma tigrinum stebbinst*
Salamander, Jemez Mountains	*Plethodon neomexicanus*
Salamander, Sacramento Mountain	*Aneides hardii*
Toad, Colorado River	*Bufo alvarius*
Toad, Great Plains Narrowmouth	*Gastrophryne olivacea*
Toad, Sonoran Green	*Bufo retiformis*
Toad, Western (Boreal)	*Bufo boreas*
Avocet, American	*Recurvirostra americana*
Beardless Tyrannulet, Northern	*Camptostoma imberbe*
Becard, Rose Throated	*Pachyramphus aglaiae*
Bittern, American	*Botaurus lentiginosus*
Bittern, Least	*Ixobrychus exilis*
Black Hawk, Common	*Buteogalius anthracinus*
Bobolink	*Dolichonyx orysivorus*
Bobwhite, Masked	*Colinus virginianus ridgwayi*
Bunting, Varied	*Passerina versicolor*
Caracara, Crested	*Polyborus plancus*
Catbird, Gray	*Dumetella carolinensis*
Cormorant, Double Crested	*Phalacrocorax auritus*
Cormorant, Olivaceous	*Phalacrocorax olivaceus*
Crane, Whooping	*Grus americana*
Cuckoo, Yellow Billed	*Coccyzus americanus occidentalis*
Curlew, Long Billed	*Numenius americanus*
Eagle, Bald	*Haliaeetus leucocephalus*
Egret, Great	*Casmerodius albus*
Egret, Snowy	*Egretta thula*
Falcon, American Peregrine	*Falco peregrinus anatum*
Falcon, Aplomado	*Falco femoralis septentrionalis*
Falcon, Arctic Peregrine	*Falco peregrinus tundrius*
Falcon, Prairie	*Falcon mexicanus*
Flycatcher, Buff Breasted	*Empidonax fulvifrons*
Flycatcher, Willow	*Empidonax trailii extimus*
Gnatcatcher, Black Capped	*Polioptila nigriceps*
Goshawk, Apache Northern	*Accipiter gentilis apache*
Goshawk, Northern	*Accipiter gentilis*
Grosbeak, Pine	*Pinicola enucleator*
Ground Dove, Common	*Columbina passerina*
Grouse, Sage	*Centrocercus urophasianus*
Hawk, Ferruginous	*Buteo regalis*
Hawk, Gray	*Buteo nitidus*
Hawk, Harris	*Parabuteo unicinctus*
Hawk, Sharp Shinned	*Accipiter striatus*
Hawk, Swainson's	*Buteo swainsoni*
Hawk, Zone Tailed	*Buteo albonotatus*
Heron, Green Backed	*Butorides striatus*
Hummingbird, Berylline	*Amazilia beryllina*
Hummingbird, Blue Throated	*Lampornis clemenciae*
Hummingbird, Broad Billed	*Cynanthus latirostris*
Hummingbird, Costa's	*Calypte costae*
Hummingbird, Lucifer	*Calothorax lucifer*
Hummingbird, Violet Crowned	*Amazilia violiceps*
Hummingbird, White Eared	*Hylocharis leucotis*
Ibis, White Faced	*Plegadis chihi*
Junco, Yellow Eyed	*Junco phaeonotus*
Kingbird, Thick Billed	*Tyrannus crassirostris*
Kingbird, Tropical	*Tyrannus melancholicus*
Kingfisher, Belted	*Ceryle alcyon*
Kite, Black Shouldered	*Elanus caeruleus*
Kite, Mississippi	*Ictinia mississippiensis*
Night Heron, Black Crowned	*Nycticorax nycticorax*
Nightjar, Buff Collared	*Caprimulgus ridgwayi*
Osprey	*Pandion haliaetus carolinensis*
Owl, Boreal	*Aegolius funereus*
Owl, Flammulated	*Otus flammeolus*
Owl, Mexian Spotted	*Strix occidentalis lucida*
Parrot, Thick Billed	*Rhynchopsitta pachyrhyncha*
Pelican, Brown	*Pelecanus occidentalis*
Pipit, Sprague's	*Anthus spragueii*
Plover, Mountain	*Charadrius montanus*
Plover, Piping	*Charadrius melodus*
Plover, Western Snowy	*Charadrius alexandrinus nivosus*
Ptarmigan, white Tailed	*Lagopus leucurus*
Pygmy Owl, Ferruginous	*Glaucidium brasilianum*
Rail, Yuma Clapper	*Rallus longirostris yumanensis*
Redstart, American	*Setophaga ruticilla*
Sandpiper, Upland	*Bartramia longicauda*
Sora	*Porzana carolina*
Sparrow, Baird's	*Ammodramus bairdii*
Sparrow, Five Striped	*Amphispiza quinquestriata*
Stilt, Black Necked	*Himantopus mexicanus*
Tern, Least	*Sterna antillarum athalassos*
Towhee, Abert's	*Pipilo aberti*
Trogon, Elegant	*Trogon elegans*
Turkey, Gould's	*Meleagris gallopavo mexicana*
Veery	*Catharus fuscescens*
Vireo, Arixona Bell's	*Vireo bellii arixonae*
Vireo, Bell's	*Vireo bellii*
Vireo, Gray	*Vireo vicinior*

Animals (Cont'd.)

Common name	Scientific name
Whistling Duck, Black Bellied	*Dendrocygna autumnalis*
Woodpecker, Gila	*Melanerpes uropygialis*
Catfish, Headwater	*Ictalurus lupus*
Catfish, Yaqui	*Ictalurus pricei*
Chub, Bonytail	*Gila elegans*
Chub, Chihualhua	*Gila nigrescens*
Chub, Gila	*Gila intermedia*
Chub, Humpback	*Gila cypha*
Chub, Roundtail	*Gila robusta*
Chub, Sonora	*Gila ditaenia*
Chub, Speckled	*Hybopsis aestivalis tetranemus*
Chub, Yaqui	*Gila purpurea*
Dace, Southern Redbelly	*Phoxinus erthrogaster*
Dace, Speckled	*Rhinichthys osculus*
Logperch, Bigscale	*Percina macrolepida*
Minnow, Loach	*Tiaroga cobitus*
Minnow, Rio Grande Silvery	*Hybognathus amarus*
Minnow, Suckermouth	*Phenacobius mirabilis*
Pupfish, Desert	*Cyprinodon macularius macularius*
Redhorse, Gray	*Moxostoma congestum*
Shiner, Arkansas River	*Notropis girardi*
Shiner, Rio Grande Bluntnose	*Notropis simus simus*
Shiner, Yaqui	*Notropis formousus mearnsi*
Spikedace	*Meda fulgida*
Spinedace, Little Colorado	*Lepidomeda vittata*
Squawfish, Colorado	*Ptychocheilus lucius*
Stoneroller, Arizona Mexican	*Campostoma ornatum pricei*
Sucker, Bluehead	*Pantosteus discobolus*
Sucker, Razorback	*Xyrauchen texanus*
Sucker, Yaqui	*Catostomus bernardini*
Tetra, Mexican	*Astyanai mexicanus*
Topminnow, Gila	*Poeciliopsis occidentalis occidentalis*
Topminnow, Yaqui	*Poeciliopsis occidentalis sonoriensis*
Trout, Apache	*Salmo apache*
Trout, Gila	*Salmo gilae*
Trout, Rio Grande Cutthroat	*Salmo clarki virginalis*
Woundfin	*Plagopterus argentissimus*
Amphipod, Arizona Cave	*Stygobromus arizonensis*
Beetle, Arizona Water Penny	*Psephenus arizonensis*
Beetle, Arizona Water Scavenger	*Cymbiodyta arizonica*
Beetle, Parker's Riffle	*Cylloepus parkeri*
Beetle, Stephan's Riffle	*Hetereimis stephani*
Beetle, White Mountains Water Penny	*Psephenus montanus*
Butterlfy, Blue Black Silverspot	*Speyeria nokomis nigrocaerulea*
Butterfly, Blue Silverspot	*Speyeria nokomis caerulescens*
Butterfly, Hydaspe Fritillary	*Speyeria hydaspe conquista*
Butterfly, Mountain Silverspot	*Speyeria nokomis nitocris*
Butterfly, Obsolete Viceroy	*Limenitis archippus obsoletus*
Grasshopper, Pinaleono Monkey	*Eumorsea pinaleno*
Mayfly, False Ameletus	*Ameletus falsus*
Mussel, Papershell	*Anodonta imbecillis*
Mussel, Pope's	*Popenaias popei*
Pea Clam, Circular	*Musculium partumeium*
Pea Clam, Lilljeborgs	*Pisidium lilljeborg*
Pea Clam, Raymond's	*Musculium raymondi*
Pea Clam, Sangre de Cristo	*Pisidium sanguinichristi*
Pea Clam, Wide	*Musculium transversum*
Snail, Alamosa Spring	*Tryonia alamosae*
Snail, Gial Spring	*Fontelicella gilae*
Snail, Linnaeus' Ramshorn	*Gyraulus crista*
Snail, New Mexico Ramshorn	*Pecosorbis kansasensis*
Snail, Say's Pond	*Lymnaea Caperata*
Snail, Socorro Spring	*Fontelicella neomexicana*
Snail. New Mexico Hotspring	*Fontelicella thermalis*
Bat, Big Longnose	*Leptonycteris nivalis*
Bat, California Leafnose	*Macrotus californicus*
Bat, Eastern Small-footed	*Myotis subulatus leibii*
Bat, Greater Mastiff	*Eumops perotis californicus*
Bat, Mexican Freetailed	*Tadarida brasiliensis*
Bat, Mexican Long-tonged	*Choeronycteris mexicana*
Bat, Occult	*Myotis lucifugus occultus*
Bat, Red	*Lasiurus borealis*
Bat, Sanborn's Long-nosed	*Leptonycteris sanborni*
Bat, Southern Yellow	*Lasiurus ega*
Bat, Southwestern Cave	*Myotis velifer brevis*
Bat, Spotted	*Euderma maculatum*
Bat, Underwoods Mastiff	*Eumops underwoodi*
Bat, Western Big-eared	*Plecotus townsendii pallescens*
Chipmunk, Penasco	*Eutamias minimus atristriatus*
Coati	*Nasua nasua*
Ferret, Black-footed	*Mustela nigripes*
Fox, Swift	*Vulpes velox*
Gopher, Cebolleta Pocket	*Thomomys umbrinus paquate*
Gopher, Graham Mountains Pocket	*Thomomys umbrinus grahamensis*
Gopher, Guadalupe Pocket	*Thomomys umbrinus guadalupensis*
Gopher, Mearn's Pocket	*Thomomys umbrinus mearnsi*

Appendix B (Cont'd.)

Animals (Cont'd.)

Common name	Scientific name	Common name	Scientific name
Gopher, Pajarito Pocket	*Thomomys umbrinus quercinus*	Squirrel, Santa Catalina Mtns.	*Sciurus arizonensis catalinae*
Jackrabbit, White-sided	*Lepus callotis*	Squirrel, White Mts Ground	*Spermophilus tridacemlineatus monticola*
Jaguar	*Felis onca*		
Marten, Pine	*Martes americana*	Vole, Arizona Montane	*Microtus montanus arizonensis*
Mink	*Mustela vison energumenos*		
Mouse, Chiricahua Harvest	*Reithrodontomys megalotus arizonensis*	Vole, Graham Mountains	*Microtus longicaudus leucophaeus*
Mouse, Coconino Pocket	*Perognathus amplus amnodytes*	Vole, Hualapai Mexican	*Microtus mexicanus hualapaiensis*
Mouse, Meadow Jumping	*Zapus hudsonius luteus*	Wolf, Mexican Gray	*Canis lupus baileyi*
Mouse, Palo Duro	*Peromyscus comanche*	Woodrat, Santa Catalina Mtns.	*Neotoma, Mexicana bullata*
Mouse, Silky Pocket	*Perognathus flavus goodpasteri*	Cooter, River	*Pseudemys concinna*
		Gila, Monster	*Heloderma suspectum*
Mouse, Wupatki Pocket	*Perognathus amplus cineris*	Kingsnake, Desert	*Lampropeltis getulus splendida*
Ocelot	*Felis pardalis*		
Otter, River	*Lutra canadensis*	Lizard, Bunch Grass	*Sceloporus scalaris*
Pika, Goat Peak	*Ochotona princeps nigrescens*	Lizard, Round-tailed Horned	*Phrynosoma modestum*
		Lizard, Texas Horned	*Phrynosoma cornutum*
Prairie Dog, Arizona	*Cynomys ludovicianus arizonensis*	Massasauga	*Sistrurus catenatus*
		Rattlesnake, Arizona Ridge-nosed	*Crotalus willardi willardi*
Prairie Dog, Black-tailed	*Cynomys ludovicianus*	Rattlesnake, Ridgenose	*Crotalus willardi*
Pronghorn, Chihuahua	*Antilocapra americana mexicana*	Rattlesnake, Mottled Rock	*Crotalus lepidus*
		Skink, Arizona Gilbert's	*Eumeces gilberti arizonensis*
Rat, Camp Verde Arizona Cotton	*Sigmodon arizonae arizonae*		
Ringtail	*Bassariscus astutus*	Skink, Mountain	*Eumeces callicephalus*
Sheep, Desert Bighorn	*Ovis canadensis mexicana*	Snake, Green Rat	*Senticolis triaspis*
Sheep, Rocky Mountain Bighorn	*Ovis canadensis nelsoni*	Snake, Mexican Garter	*Thamnophis eques*
Shrew, Arizona	*Sorex arizonae*	Snake, Narrow-headed Garter	*Thamnophis rufipunctatus*
Shrew, Desert	*Notiosorex crawfordi*	Snake, Plain-bellied Water	*Nerodia erythrogaster*
Shrew, Northern Water	*Sorex palustris*	Snake, Texas Long-nosed	*Rhinocheilus lecotei tessellatus*
Squirrel, Chiricahua	*Sciurus nayaritensis chiricahuae*		
		Snake, Vine	*Oxybelis aeneus*
Squirrel, Kaibab	*Sciurus aberti kaibabensis*	Snake, Western Ribbon	*Thamnophis proximus*
Squirrel, Mt. Graham Red	*Tamiasciurus hudsonicus grahamensis*	Tortoise, Desert	*Gopherus agassizii*
		Whiptail, Gray Checkered	*Cnemidophorus dixoni*
		Whiptail, Giant Spotted	*Cnemidophorus burti*

Plants

Scientific name	Scientific name	Scientific name
Abutilon parishii	*Amsonia grandiflora*	*Aster potosinus*
Agave arizonica	*Amsonia Kearneyana*	*A.lemmonii*
Agave delamateri (sp. *Nova*)	*Aquilegia chaplinei*	*Astragalus accumbens*
Agave murpheyi	*Aquilegia desertorum*	*Astragalus altus*
Agave parviflora	*Argemono arizonica*	*Astragalus ampullarius*
Agave schottii	*Argemone pleiacantha*	*Astragalus cobrensis*
Agave tontobasinensis	ssp. *pinnatisecta*	var. *maguirei*
Allium gooddingii	*Aster horridus*	*Astragalus cremnophylax*
Amoreuxia gonzalezii	*Aster laevis* var. *guadalupensis*	var. *cremnophylax*

Plants (Cont'd.)

Scientific name	Scientific name	Scientific name
Astragalus cremnophylax	*Erigeron heliographis*	*(Psoralea trinervata)*
var. *myriorraphis*	*Erigeron hessii*	*Pediomelum pentaphyllum*
Astragalus hypoxylus	*Erigeron kuschei*	*Penstemon alamosensis*
Astragalus kerrii	*Erigeron lemonii*	*Penstemon clutei*
Astragalus nutriosensis	*Erigeron piscaticus*	*Penstemon discolor*
Astragalus ripleyi	*Erigeron rhizomatus*	*Penstemon distans*
Astragalus wittmannii	*Erigeron sivinskii*	*Penstemon pseudoparvus*
Browallia sp. *nova*	*Erigeron subglaber*	*Penstemon pseudoputus*
Camissonia confertiflora	*Eriogonum aliquantum*	*(P. virgatus* ssp. *pseudoputus)*
Camissonia exilis	*Eriogonum apachense*	*Perityle saxicola*
Capsicum annuum	*Eriogonum capillare*	*Phacelia senata*
var. *glabriusculum*	*Eriogonum mortonianum*	*Phacelia welshii*
Castilleja kaibabensis	*Eriogonum ripleyi*	*Phaseolus (Macroptilium) supinus*
Castillja mogollonica	*Eriogonum thompsonae*	*Pherotrichis balbisii*
Cereus greggii var.	var. *atwoodii*	*Polemonium pauciflorum*
transmontanus	*Euphorbia plummerae*	ssp. *hinckleyi*
Chaetopappa elegans	*Fraxinus gooddingii*	*Polygala rimulicola*
Chaetopappa hersheyi	*Gentianella Wislizenii*	var. *rimulicola*
Cheilanthes pringlei	*Graptopetalum bartramii*	*Potentilla multifoliolata*
Choisya mollis	*Haplopappus microcephalus*	*Potentilla sierrae-blancae*
Chrysothamnus molestus	*Hedeoma apiculatum*	*Primula hunnewellii*
Cimicifuga arizonica	*Hedeoma diffusum*	*Psorothamnus*
Cirsium parryi ssp. *mogollonicum*	*Hedeoma todsenii*	*Thompsonnia* evar. *whitingii*
Cirsium vinaceum	*Heterotheca cutteri*	*Pteryxia davidsonii*
Clematis hirsutissima	*Herrickia horrida*	*Purshia subintegra*
var. *arizonica*	*(Aster horridus)*	*(Cowania subintegra)*
Cleome multicaulis	*Hexalectris nitida*	*Rosa stellata* ssp. *abyssa*
Colubrina californica	*Hexalectris warnockii*	*Rumex orthoneurus*
Conioselinum mexicanum	*Hieraceum pringlei*	*Salix arizonica*
Coryphantha recurvata	*Ipomopsis sanctispiritus*	*Salvia amissa*
Coryphantha robbinsorum	*Lesquerella aurea*	*Salvia dorrii* var. *mearnsii*
Coryphantha scheeri	*Lesquerella kaibabensis*	*Scrophularia macrantha*
var. *robustispina*	*Lilaeopsis schaffneriana*	*Senecio franciscanus*
Coryphantha sneedii var. *sneedii*	ssp. *recurva*	*Senecio huachucanus*
Coryphantha (Escobaria) villardii	*(L. recurva)*	*Senecio quaerens*
Coursetia glabella	*Lilium parryi*	*Silene rectiramea*
Cynanchum wigginsii	*Lilium philadelphicum*	*Sophora arizonica*
Dalea tentaculoides	*Limosella pubiflora*	*Sophora gypsophila*
var. *gentry indigobush*	*Manihot davisiae*	var. *guadalupensis*
Desmanthus bicornutus	*Margaranthus lemmonii*	*Spiranthes delitescens*
Draba standleyi	*Notholaena lemmonii*	*Spiranthes graminea*
Echinocereus fendleri	*Opuntia viridiflora*	*Stipa curvifolia*
var. *kuenzieri*	*Pectis imberbis*	*Streptanthus lemmonii*
Echinocereus ledingii	*Pediocactus bradyi*	*Streptanthus carinatus*
Echinocereus Lloydii	*Pediocactus*	*Strepranthus sparsiflorus*
Echinocereus triglochidiatus	*papyracanthus*	*Talinum humile*
var. *arizonicus*	*(Toumeya)*	*Talinum marginatum*
Echinomastus (Neolloydia)	*Pediocactus paradinei*	*Talinum validulum*
erectocentrus var. *erectocentrus*	*Pediocactus peeblesianus*	*Trifolium neurophyllum*
Erigeron anchana	var. *fickeiseniae*	*Tumamoca macdougallii*
Erigeron arizonicus	*Pediocactus sileri*	*Vauquelinia californica*
Erigeron eriophyllus	*Pediomelum trinervatum*	ssp. *pauciflora*

[1] *Source = USDA Forest Service, Region 3*

Appendix C

Glossary

Human disturbance: see human influence.

Adaptive management: implementing policy decisions as an ongoing process that requires monitoring the results. Applying scientific principles and methods to improve resource management activities incrementally as managers and scientists learn from experience and new scientific findings and adapt to social changes and demands.

Biodiversity: the variety of life and its processes including that in genes, species, ecosystems, and ecological processes.

Classification: the assignment of points or sample units to a finite number of discrete types, usually based on an analysis of many variables such as vegetation or soil classification.

Commodity output: the supply of goods or services taken from or supplied by a resource area.

Conservation: the protection, use, and planned management of living organisms and their vital processes to prevent their depletion, exploitation, destruction, or waste.

Cumulative effect: the affect on the environment that results from the incremental impact of a proposed action when added to other past, present, and reasonably foreseeable future actions.

Decision support model: an organized system that policy makers and managers can use to assist in selecting a course of action; often, but not necessarily, a formal model.

Disturbance: a discrete event, either natural or human induced, that disrupts the structure or dynamics of an ecological system; for example, fire, flood, defoliation, timber harvest, road construction, etc.

Ecological principles: the biological basis for sound ecosystem management through which ecosystem sustainability is ensured.

Ecological process: the actions or events, such as disturbance, successional development, nutrient cycling, carbon sequestration, productivity, and decay, that link organisms (including humans) and their environment.

Ecosystem: living organisms interacting with each other and their physical environment.

Ecosystem composition: the constituent elements of an ecosystem.

Ecosystem function: the processes, including biogeochemical processes and vegetation succession, through which the constituent living and nonliving elements of ecosystems change and interact.

Ecosystem management: the use of an ecological approach that combines social, physical, economic, and biological needs and values to assure productive, healthy ecosystems.

Ecosystem restoration: returning an ecosystem from a nonsustainable to a sustainable condition.

Ecosystem structure: the spatial arrangement of the living and nonliving elements of an ecosystem.

Ecosystem sustainability: the ability to sustain diversity, productivity, resilience to stress, health, renewability, and/or yields of desired values, resource uses, products, or services from an ecosystem while maintaining the integrity of the ecosystem over time.

Element: an identifiable component, process, or condition of an ecosystem.

Endangered species: any species that is in danger of extinction throughout all or a significant portion of its range.

Exotic or non-native species: a species introduced into an ecosystem through human activities.

Forest and rangeland health: a condition where natural ecosystems have the capacity across the landscape for renewal, for recovery from a wide range of disturbances, and for retention of ecological resilience while meeting current and future needs of people for desired levels of values, uses, products, and services.

Healthy ecosystem: an ecosystem in which structure and functions allow maintenance of the desired condition of biological diversity, biotic integrity, and ecological processes over time.

Historical ecosystem: an ecosystem at a specified previous time.

Human dimension: an integral component of ecosystem management that recognizes that people are part of ecosystems, that their pursuit of past, present, and future desires, needs, and values have influenced and will continue to influence ecosystems, and that ecosystem management must include consideration of the physical, emotional, mental, spiritual, social, cultural, and economic well-being of people and communities.

Human influence: a disturbance or change in ecosystem composition, structure, or function caused by humans.

Landscape: an area composed of interacting ecosystems that are repeated because of geology, land form, soils,

climate, biota, and human influences throughout the area. Landscapes are generally of a size, shape, and pattern which is determined by interacting ecosystems.

Natural disturbance: the periodic impact of natural events such as fire, flood, severe drought, insect or disease attack, or wind.

Natural ecosystem: an ecosystem that is minimally influenced by humans and that is, in the larger sense, diverse, resilient, and sustainable.

Natural variation: the spectrum of conditions possible in ecosystem composition, structure, and function considering both temporal and spatial factors.

Productive: the ability of an area to provide goods and services, and to sustain ecological values.

Resilience: the ability of an ecosystem to maintain the desired condition of diversity, integrity, and ecological processes following disturbance.

Restoration: actions taken to modify an ecosystem in whole or in part to achieve a desired condition.

Scale: the degree of resolution at which ecological processes, structures, and changes across space and time are observed and measured.

Sensitive species: those plant and animal species identified by a Regional Forester for which population viability is a concern as evidenced by: (a) significant current or predicted downward trends in population numbers or density; or (b) significant current or predicted downward trend in habitat capability that would reduce a species' existing distribution.

Southwest: the states of Arizona and New Mexico.

Succession: an active process of directional change in both organisms and physical characteristics as available organisms modify and respond to changes in the environment.

Sustainability: the ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time.

Threatened species: any species that is likely to become an endangered species within the foreseeable future through all or a significant portion of its range.

Watershed: an area of land with a characteristic drainage network that contributes surface or ground water to the flow at that point; a drainage basin or a major subdivision of a drainage basin.

You may order additional copies of this publication by sending your mailing information in label form through one of the following media. Please send the publication title and number.

Telephone (490) 498-1719

DG message D.Schneider:S28A

FAX (490) 498-1660

E-mail /s=r.schneider/ou1=s28a@mhs-fswa.attmail.com

Mailing Address Publications Distribution
Rocky Mountain Forest and Range
Experiment Station
3825 E. Mulberry Street
Fort Collins, CO 80524

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of seven regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota

*Station Headquarters: 240 W. Prospect Rd., Fort Collins, CO 80526